NOTES FROM A WORKSHOP
ON
GAS SUPERSATURATION AND ITS RESEARCH NEEDS IN THE COLUMBIA RIVER*

April 19-20, 1994

at the
Coliseum Red Lion
Portland, OR

Gerald R. Bouck, Editor

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All principle speakers have reviewed these notes.

Gas Supersaturation and its Research Needs in the Columbia River

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April 19 - Morning Session

Introduction. G. R. Bouck, Division of Fish and Wildlife, BPA Portland, OR.

Introductory comments were given by Dr. Gerald R. Bouck, Senior Fisheries Scientist at BPA, who organized the workshop. He said there were four objectives: 1) Review of present and probable future supersaturation on the Columbia and Snake Rivers; 2) Provide peer review and comment on existing gas supersaturation research projects; 3) Have experts on gas supersaturation list and prioritize additional research needs; and 4) Provide a record of the meeting and update the 1980 ***AFS*** report on ***Atmospheric Gas Supersaturation: Educational and Research Needs (TAFS 109: 769).***

The meeting was then turned over to facilitator, Mr. Hugh Moore, who noted that earlier plans for a two day session (April 19-20) had changed. A number of attendees wanted to participate in a workshop on stress the afternoon of April 20. As a result, the plenary session ended at noon April 20 and most of the attendees left, but the panel of experts continued the afternoon in executive session. The latter was spent on resolving specific question, and resolving research priorities.

Telescoping the schedule, Moore said, would require particularly close attention to time limits by people delivering presentations. More reminded the group that the workshop was limited to technical issues associated with gas supersaturation. The event will be of use to policy makers, he said, but added that the workshop was not an appropriate forum for the discussion of policy matters.

Historic and Current Supersaturation in the Columbia and Snake Rivers. Wesley J. Ebel, National Marine Fisheries Service (retired), Seattle, WA.

Dr. Ebel provided the following background information. Dissolved gas supersaturation was first reported in the Columbia River in the early 1960s by Dr. Dick Westgard (Washington Dept. of Fisheries). Westgard was investigating adult chinook mortality in the McNary spawning channel, which was supplied with water from the Columbia River. Subsequently, a NMFS survey found gas saturation levels exceeded 130 % of barometric pressure at John Day Dam in 1968, when only one turbine was in operation. During the high flow year of 1969, Ebel said, the entire river was above 120 percent saturation.

Completion of dam construction on the lower Snake in 197 1 and 72 increased peril for migrating fish he said. They could now be exposed to gas supersaturation from Little Goose to Bonneville Dams, a journey of from three to four weeks in duration.

Spill was reduced as projects were completed and turbines installed in empty bays. The installation of spill deflectors (flip-lips) also mitigated supersaturation. By the early 1980s Ebel continued, it was believed that the problem had been essentially solved.

Spills in recent years have been re instituted to assist downstream migrating salmonids and this has produced a recurrence of significant gas supersaturation. Studies in 1985-86 disclosed levels as high as 130 percent for short periods of time at Ice Harbor Dam. Levels were usually less than 120 percent but some external signs of gas bubble disease were detected in downstream migrants.

Relatively high flows last year produced supersaturation levels of between 120 % and 130 % for a short period in late April and late May, he said, and some injury to fish may have occurred.

Ebel said attention should be given to the Ice Harbor project, where major spill for fish is scheduled. He showed slides of fish taken from Lower Granite in 1993, with extensive dermal lesions on the top of the head, called "head bum," and said this may or may not be attributable to gas supersaturation. Pictures of fish which suffered from gas bubble disease in earlier years were shown but these symptoms did not exactly match abrasions on the fish taken in 1993

Bouck said that a similar lesion had been reported 20 or so years ago by Jerry Mallet (Idaho's Dept. of Fish and Game) in chinook arriving at hatcheries and it seemed to be related to high flows and high gas levels. Bouck thought that if supersaturation was involved, one possible explanation was fish collisions with structures, caused by temporarily blindness due to hemostasis from gas emboli in the ophthalmic artery, or possibly due to gas bubbles in the lateral line. Blind adult salmon, especially sockeye, used to be common when gas levels were high in the late 1960's.

Earl Dawley, NMFS, was dubious about the connection between head bum symptoms and gas bubble disease. If the head bum lesion was attributable to supersaturation, he said, there should be other symptoms.

Ebel agreed that conclusions could not be drawn from one observation at one location.

Larry Fidler, Aspen Applied Sciences, wondered if the afflicted fish were wild or hatchery stock. They were both, Ebel replied.

Recalling his investigations of gas bubble disease in the 1960s Kirk Beiningen, Oregon Department of Fish and Wildlife, said he did not recall seeing this sort of head bum.

One problem with studies conducted in the 1960s Ebel observed, was the failure to follow up, with long-term studies "to see what happened later."

Projected Gas Levels for Future Hydro Operations. Dr. Bolyvong Tanovan, Corps of Engineers' Reservoir Control Center, Portland, OR.

Dr. Tanovan said there was no perceived supersaturation problem when he "came on the scene" in 1983 Interest in the issue was revived by the implementation of spill to improve downstream fish survival efficiency.

A review of the literature indicated that stilling basins were studied in the 1970s and the monitoring of forebays occurred in the 1980s Tanovan continued. Currently, a need to look at tailwater areas has been recognized.

Compared with the 13 monitoring stations which were operated in the 198Os, there are 33 today. The development of a computer model to predict levels of dissolved gas began in 197 1 This one dimensional model simulated the effect of spills on dissolved gas levels from the Chief Joseph Dam on the Columbia and Lower Granite Dam on the Snake to below Bonneville Dam.

The model was revised in 1986, when it became known as GASSPILL. It was developed to be used as an optimization tool in controlling dissolved gas while meeting system energy loads. As mentioned earlier, however, the importance of supersaturation as a problem had by then declined and the model was not used extensively.

Spill to aid migrating salmonids and reservoir drawdown proposals revived interest in the model, which is now being used to predict dissolved gas levels produced by various levels of spill. It was employed extensively in the current System Operation Review, a comprehensive study of federal projects in the Columbia Basin by the Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration..

Tanovan characterized GASSPILL as "a nice tool, but only a tool". Two shortcomings of the current version, he said, are its one dimensional structure and an inability to calculate the impact of short term spills. Spills to benefit fish are often no longer than six hours in duration.

The proposed 80 percent fish passage efficiency goal, which could require considerable spill, has focused attention on possible dissolved gas problems, Tanovan noted. There is also concern about routine violations of the 110 percent standard for dissolved gas saturation.

Gary Johnson, BPA, asked how accurate GASSPILL predictions have been.

Depending on "where you get the entrainment coefficient," Tanovan replied, within about 10 percent of observed data. Asked which dimension the one dimension of GASSPILL is, he said it is lateral.

Fidler asked whether the model distinguishes between dissolved oxygen and dissolved nitrogen and Tanovan said that it doesn't. In some situations, Fidler continued, pulses of dissolved oxygen from photosynthesis contribute to supersaturation. Tanovan suggested exploring the possibility of adding a component to the model to address this phenomenon.

Mike McCann, University of Washington School of Fisheries, said people working with the CRiSP fish survival model have had trouble calibrating results from GASSPILL. Levels of nitrogen tend to peak and then decline, he continued, and asked Tanovan for a response.

Tanovan said this is caused by the shape of the air entrainment versus spill relationship specific in the model for some of the dams. He welcomed any assistance in improving the quality of the modeling effort.

Regarding the goal of 80 percent fish passage efficiency, Steve Pettit, Idaho Fish and Game Department, said it "is not all or nothing." Spill would be reduced if symptoms of gas bubble disease materialize.

Anadromous and Resident Fish Assemblages in the Columbia and Snake Rivers of Concern to Supersaturation. Mr. Ray Beamesderfer, Oregon Department of Fish and Wildlife, Clackamus, Oregon,

Mr. Beamesderfer described the assemblage of fish species subject to the effects of supersaturation in the Columbia and Snake Rivers. Too often, he said, the river system is considered "a pipeline" available to facilitate a variety of economically important activities. There is a tendency to lose sight of the fact that it is a complex ecosystem. Research has concentrated on the effect of gas supersaturation on salmonids, he noted, primarily on downstream migrating juveniles. Information is scarce on supersaturation impacts to resident fish.

Generally, Beamesderfer said, primary production in the Columbia system is low. Fluctuations in the river level, even before the construction of dams, favored species which can adapt to this condition. Because of daily fluctuations, littoral zones are unproductive; backwater habitat is also limited. The river gradient is relatively low and reservoirs are filling with sediment.

In addition to anadromous species, major inhabitants include the grazers (suckers and chub), benthivores (juvenile white sturgeon, and prickly sculpin), and picivores (predators like the northern squawfish, walleye, bass, catfish, and adult sturgeon.).

Among introduced fish, shad are "increasing exponentially", Beamesderfer reported. The species has apparently found a previously unoccupied niche and has added a "huge biomass" to the river system. Other common introduced species include smallmouth bass, walleye (both of which eat salmonids), channel catfish, and carp. A number of other species (bull trout and white fish) sometimes enter the Columbia and Snake from tributaries.

Data about the effects of gas supersaturation are scarce, Beamesderfer continued, but he suggested this order of vulnerability: 1) downstream migrating anadromous smolts; 2) introduced fish which dwell in shallow water; 3) predators; 4) grazers.

He said species which spawn during periods when significant spilling occurs may be exposed to supersaturation.

Dr. William Krise, National Biological Survey, asked about the effect of 102 to 104 percent supersaturation on fish reproduction in the river. There is no data on the subject, Beamesderfer replied.

What accounts for the rapid increase in shad, Bouck wondered. Beamesderfer indicated the Columbia appears to be perfect shad habitat.

The Regulatory Frame of Reference for Gas Supersaturation. Bill Sobolewski, Environmental Protection Agency, Portland, OR.

Mr. Sobolewski introduced the subject of regulation with a reminder that the 110 percent dissolved gas standard was adopted by state water quality agencies. EPA is concerned about violations of water quality standards because of a suit against the EPA regarding phosphorus in the Tualatin River. The agency is also concerned about enforcement of the Water Quality Act in the Columbia. Experiments on the effects of gas supersaturation in the laboratory led to the development of water quality criteria on gas supersaturation. This was published in 1986 and used by the states to develop standards.

States review their water quality standards every three years, he said, and Oregon has recently completed its triennial review. It retained the 110 percent standard for dissolved gas.

The Idaho standard is based on discharges, he said, but since dams are not considered point sources, spills are not regulated. The Corps of Engineers was asked to conduct bioassay studies at Bonneville Dam after it was noted that spill in the 1980's exceeded the 110% standard. An EPA legal opinion indicated that these studies were unnecessary because a standard already exists.

The lack of enforcing water quality violations creastes, Sobolewski declared, a situation in which the EPA and the states are vulnerable to law suits, "which is no way to solve any environmental problem."

Margaret Filardo, Fish Passage Center, asked how supersaturation levels are measured.

"Whatever gas is in the water column when samples are taken," Sobolewski replied.

Greg Robart, ODFW, thought it obvious that dams are a point source for gas supersaturation.

Given the non-degradation clause in the Water Quality Act, Bouck asked how the gas supersaturation standard could be relaxed to allow higher gas pressures?

States can relax standards, Sobolewski said, but noted that efforts by the Oregon DEQ to relax the standards for a pulp mill was rejected by their Environmental Quality Commission.

Fidler asked if the EPA had a protocol for addressing insufficiencies in data when it developed its supersaturation criteria. Sobolewski thought not and Fidler wondered what would happen if such a protocol were developed now.

Eric Schlorff, Washington Department of Ecology, said the possibility of changing the 110 percent standard in Washington State could be evaluated during the next triennial review. Currently, he said, short term modification of the standard is permitted. Given the frequency with which the current standard is exceeded, he said, studies to determined the appropriateness of change may need to be undertaken.

Beiningen asked if faster action might not be taken outside of the three year review cycle. There is an emergency **clause,** Schlorff said, which takes about 45 days to evoke.

"What would it take to change a standard?," Bouck asked.

It would take consultation with current experts, Schlorff replied, and said the largest knowledge gap appears to be associated with effects to non-anadromous species.

A discussion of jurisdiction, state and federal authority, then **ensued.** Bouck if and how states can control federal actions. This can be done indirectly because Congress requires the states to administer federal laws, Schlorff declared.

What would happen on the Columbia, if Washington's supersaturation standard was significantly different than Oregon's?, Bouck wondered. The standard can be different so long as the state standards are more stringent than federal standards, and the example of California's **auto** emission regulations was cited. States **issue permits** for federal facilities based on compliance with state standards, Sobolewski noted.

John McKern, COE, said federal agencies have frequently transferred authority to the states in several areas to reduce duplication and staffing.

How Should Gas Supersaturation Standards be Set? (Group discussion)

"Why are we here?," Gary Fredricks, NMFS, asked. Because "we don't have a good feeling about how far we can go with spill" to promote the **survival** of downstream migrating salmonids, he answered. Current and expected Endangered Species Act listings lend urgency to efforts to address this problem, Fredricks added.

Current measures include a Corps of Engineers spill study (possible installation of additional spill deflectors at Ice Harbor and John Day dams) and continued development of the GASSPILL model.

"We're in the condition of crisis management," Fredricks declared, and raised the possibility of unscientific court decisions on spill. He challenged the group to develop an approach to determining limitations on spill imposed by gas supersaturation.

Schlorff said it was his understanding that effects of spill on anadromous fish are fairly well understood.

Yes, in the laboratory, Fredricks replied, but not in the complex river ecosystem.

What sort of monitoring will be required to answer the critical questions?, Bill Maslen, BPA, asked.

In British Columbia, Fidler reported, a 110 percent supersaturation standard was set for deeper water (greater than 7/l 0 of a meter in depth). The standard is more constraining in shallow water. This guideline is still being evaluated, he said, and there are those who advocate a 103 percent level.

People pressing for the lower standard cite concerns about the unknown sub lethal effects of gas supersaturation. It has been known since 1976 that supersaturation effects blood chemistry, Fidler continued. Adverse effects on the smoltification process, feeding, behavior, growth, and swimming ability may occur, he said. These effects are both difficult to establish and very important in terms of vulnerability to predation.

This creates the need for a risk assessment, Fredericks concluded.

Jim Nielsen, WDFW, asked if the ratio between oxygen and nitrogen was considered in the Canadian studies. It was, Fidler replied, and it was determined that the ratio can effect thresholds for gas supersaturation effects.

Bob Heinith, Columbia River Inter-Tribal Fish Commission, said a dissolved gas standard can be set but it is thrown into a quandary by the construction of a dam.

Fidler responded that legislation in Canada requires dam operators to modify their structures until the standard is met.

"But can it be done?," Heinith asked.

Fidler cited the case of the Keenleyside Dam, which was producing gas supersaturation levels of 140 percent at certain periods during the year. It was determined that less dissolved gas was produced by the north ports when water was released from this storage

project. A computer model was developed to maximize use of these north ports and gas levels are now zero for most of the year.

When standards are not met, Fidler continued, large fines are levied and "you can get arrested."

Bouck contributed another account of stiff sanctions against gas supersaturation. Salmon in net pens were being killed 25 kilometers below a small hydro project in Norway, and the authorities shut down the hydro project.

Don Reck, NMFS, agreed that a risk assessment of spill is required and solicited suggestions on how to proceed.

Krise said investigators need to determine where fish are at susceptible times. It could then be possible to develop ranking systems for the time and place for spill. There seems to be lot of data in little pieces and in many places, he said, and suggested that putting it together would be a good start.

Any risk assessment must take into account changes in system operations which have recently occurred, Dawley observed. Positive as well as negative effects from spill should be determined, he continued, and noted that examination of fish for external signs of gas bubble disease is being performed where fish are being handled.

Filardo thought involuntary and voluntary spill should be separated.

Bouck said the effects of gas supersaturation are the same, regardless of whether the cause of it was voluntary or involuntary spill.

In the 1970s Dawley observed, involuntary spills were frequently 24 hours in duration. Current voluntary spills for fish are 12 hours on, 12 hours off, he continued, and the difference in impacts needs to be established.

Voluntary spill must be managed very carefully, Fidler asserted, because nothing can be done about involuntary spill and "fish are facing a lot of other problems."

The 110 percent standard is intended to benefit all aquatic life, not just anadromous fish, Sobolewski reminded the group, and it doesn't matter whether the gas comes from voluntary or involuntary spill.

Matt Mesa, National Fisheries Research Center; agreed with Fidler that a "cumulative effects perspective" was needed, not just the assessment of a single, simple effect.

Jim Atheam, COE, asked if the examination of fish for external symptoms is enough.

No, Fidler replied, maintaining that many conditions are not revealed during external examination.

Bouck recalled that the Water Quality Act of 1968 took an approach based on the enforcement of established water quality standards. Vast numbers of bioassays were done on different toxicants and water quality criteria were set. They didn't worry about the cumulative biological effect of all the water quality parameters, rather, they enforced the violation of the standards. Eventually it became obvious that this approach was too simplistic. Fish populations and habitat kept shrinking without apparent violations of the standard. For this reason, the National Academy of Sciences recommended changing the approach to monitoring the aquatic ecosystem as a whole, not just violation of individual parameters.

Laboratory experiments were a valuable first step, but only a first step. What was needed was an assessment of relationships. Bouck wondered if a similar mistake might not be made if the group concentrates exclusively on three or four species.

Reck suggested survival studies in individual river reaches. Ebel considered this approach is "the only way." Ebel proposed the study of individual reaches under various flow conditions. It is difficult to make reach studies precise enough, he continued, but felt the reach approach was necessary to determine if fish transportation, bypass and spilling "are doing any good."

In the past, Beiningen, observed, resource managers were user oriented, concentrating on a few favored species. This is no longer acceptable. "We must manage all parts. of the ecosystem. "

This requirement must be kept in mind when enforcing the Endangered Species Act, Fredricks added.

"And if we're wrong, we might not get another chance," Fidler submitted.

McCann expressed dismay about the attempt to model salmon survival when evaluation of fish transportation, spill and bypass includes so many "unproven assumptions."

Maslen was concerned about the process of measuring dissolved gas levels. He wondered how it is measured, where, for how long, and the elevation of fish in the water column.

Tom Miller, COE, described experiments at Ice Harbor. With spill limited to 25,000 cubic feet per second, levels of dissolved gas frequently reached 120 percent. Down river, levels were often significantly different on different sides of the river. "What do we do with this kind of information?," he asked.

April 19 - Afternoon

What are the Analytical and Monitoring Research Needs In Gas Supersaturation? (Group Discussion).

Dr. Robert White, Montana Cooperative Fish Research Unit, said he thought that "it was a given" that increased flow was good for fish and that the effects of various spill patterns was known. He noted that several discussions during the previous session, called this assumption into question.

Some of the needed information is coming, Dawley replied. Survival data is being collected on the Snake and spill tests are being conducted at Lower Monumental. Information from the 33 monitoring stations should permit improvement or replacement of the GASSPILL model.

But what are the most significant needs?, Moore, the facilitator asked.

One need is a means of detecting internal gas bubbles (emboli) without killing the fish, Bouck proposed. He recalled a study in which one half of the adult spring chinook were killed by high levels of gas supersaturation (130 %) in eight hours, yet there were few external indications of gas bubble disease. They simply died too quickly to form these signs in externally visible area (except in gills).

Bouck called attention to work which is being done on an acoustical method of detecting air bubbles in the vascular system of fish without killing them. This is being done by Tom Carlson, at Battelle Northwest Labs, in Richland, Washington.

Looking for gas bubbled diseased fish in the Columbia River is a daunting task, according to Bouck. Consider the magnitude of the problem: the discharge is usually over 100,000 cfs and there are about 250,000 surface acres from the mouth up to the Snake River. He suspects that most gas bubble debilitated smolts are removed from the river by predators, thus, skewing downward the incidence of gas bubble disease. So, he asked, "how do you monitor anything as ephemeral as a gas bubble diseased smolt, in such a large space?"

Another challenge, Bouck continued, is "how do we address the issue for fish that prefer shallow water niches?"

Gas levels haven't been measure in back water areas, Ebel noted

Solar heating could drive gas levels even higher in back water areas, Fidler added

White said his research unit has been studying a 8 kilometer stretch of river for eight years and still has more questions than answers.

A need to know what kind of habitats resident fish are using was expressed and it was suggested that this information is already known. Ebel declared that only some of the necessary information is known.

The need is for information about all aquatic species at all life stages, White said.

Fish are commonly found lower in the water column when supersaturation levels are high Fidler observed. Research needs to establish if this is because of an attempt to compensate for gas induced over-buoyancy of the swim bladder or some other reason.

White recalled a test in which gas levels were manipulated in the river. Fish were fitted with depth gauges, which indicated that they didn't react to changes in supersaturation.

But these were adult fish, Fidler pointed out. Bladder over inflation depends on the size of the fish. In smaller fish, bladders over inflate and rupture. In larger fish, there is little reaction.

Bouck wondered about the persistence of gas in lower reaches of the Columbia. Heinith agreed that "we need a better handle on gas dissipation" and requested monitoring of tail water at the John Day and Dalles Dams.

Monitoring gas bubble disease in adult salmon is particularly difficult, Bouck said: "because no one is eager to let you touch the adults." Further, adults need anesthesia for examination and that presents another set of problems.

Filardo suggested including gas bubble disease examination to the task of those who are currently handling adult fish.

Mesa returned to the problem of killing some fish to seek internal evidence of bubble disease. Given the depressed populations of many stocks this "may not be acceptable."

AI Giorgi, Don Chapman Consultants, wondered if an abundant species with similar response to supersaturation could be tested in lieu of salmon.

"We do know a lot about thresholds," Fidler reminded the group. Bubble growth in the vascular system of fish begins at between 115 and 118. Some predictions can be made based on thresholds and the location of fish in the water column.

What are the Concerns and Research Needs for Anadromous Fish Relative to Gas Supersaturation? (Group Discussion)

Miller began this discussion by inquiring about the status of Tom Carlson's work on ultrasonic fish examinations for gas bubble disease.

Bouck said it was his understanding that live fish can be scanned with ultra sound equipment and the gas bubbles, being sonic barriers, should show. The swim bladders are clearly visible. The basic technical capability is there, he said, but it needs to be refined.

Noting that a turbine passage study will be conducted this summer, Miller proposed linking sonar scanning with other dissolved gas research.

John Jensen, Pacific Biological Station, B.C., suggested using what is known about the thresholds of gas bubble disease and focusing on where fish are in the water column when they are affected.

Giorgi asked what is known about the depth of migrating fish and its effects on gas bubble disease.

They are currently unknown, Fidler said, but guidelines and a protocol are being developed to address knowledge gaps, particularly those having to do with sub lethal effects. He said it is known that fish exposed for more than five hours to supersaturation above 118 percent will die. This provides a frame of reference which will be used to focus on a variety of related conditions, he indicated.

Jensen stressed the importance of recognizing the difference between the dynamic real world, where these relationships are actually played out, and conditions in the laboratory. One problem is that data disappears as conditions move away from the fish mortality threshold, he said. When this is added to the uncertainties of models used for predicting supersaturation, a very large area of uncertainty is created. He proposed making a list of things which should be recorded and pointed out that changes in circumstances -- fishing restrictions and different flow regimes -- "will make it difficult to understand what we're seeing now."

Pettit mentioned the ability of fish to move to considerable depths in the river as a problem for laboratory research. Jensen suggested doing work in the river with cages as a partial solution.

The 110 percent standard may be appropriate to prevent acute symptoms of gas bubble disease, Schlorff submitted. What may be needed, he continued, is a criteria for preventing chronic exposure conditions.

Mesa thought some understanding of the sub lethal effects of supersaturation could be achieved in the laboratory. Possibilities include information about how supersaturation increases stress and affects resistance to disease.

McCann asked about effects of supersaturation on the nervous-system of fish prior to the formation of gas bubbles. Bouck said dissolved nitrogen shouldn't be reactive at such low hydrostatic pressures, based on results from human divers.

Bouck said that research is needed to define the stimulus response mechanism when fish volitionally "avoid" gas supersaturation. "In nature, sometimes you see avoidance and sometimes you don't," he declared. The assumption that fish try to avoid supersaturation

the way they avoid toxic material is questionable, Bouck continued. He has seen plenty of fish killed by supersaturation when they could have avoided it.

Ebel noted that fish can avoid supersaturation by sounding but the data is unclear as to whether fish actually detect supersaturation and sound in response to it. In lab experiments utilizing steelhead and fall chinook, the fish did shift their distribution to deeper water when the water was supersaturated, but it was not enough to void mortality. Weitkamp and Katz (1980) concluded that "insufficient information is available to draw any useful conclusion on this issue." Atheam asked if fish would move laterally out of supersaturation and Dawley said this has not been established.

Fish behavior studies have been primarily conducted in the lab, Bouck noted, and their avoidance seems to be a response to confinement and is unreliable.

In his studies, Fidler said, fish used all the water column despite supersaturation. Smaller fish spent more time at lower levels. Larger fish (those with bigger air bladders) did not change their behavior.

Use of a "swim tube" for in-river studies of this phenomenon was suggested.

Determining survival between hydro projects would answer this, but would be difficult.

Bouck talked about the frustrations of studying cause-effect relationship in gas bubble disease because highly variable is common in times to death. Poor nutrition and fasting clearly increased susceptibility to gas bubble disease. But among healthy fish, similar exposures can produced quite different results. His tongue in cheek explanation was "demonic influences" but he suggested that such highly variable indicates random bubble formation, hence random mortality among "healthy" fish. Prior exposure to supersaturation did not increase tolerance to it.

Every fish passing a darn is subject to one atmosphere of pressure, Miller noted, and asked: "how important is depth?"

Bouck wondered if part of the explanation for inconsistent results may be because "we are measuring gas in the water not in the blood (of fish)." Perhaps the diet of fish descending the river has altered their susceptibility to supersaturation, either from fasting or from the summation of environmental plus intestinal gas.

Conversion of hatchery fish from a hatchery to a natural diet was suggested as a reason for the development of such a condition.

Regarding the significance of life stage to gas bubble disease vulnerability, Jensen noted that eggs are not as susceptible as hatched fished. In the next stage, Fidler continued, swim bladders can over inflate and rupture in fish 7 grams or less in size.

On the other hand, smaller fish (between 10 and 20 grams) appear to be more resistant to the development of bubbles in vascular systems.

Miller returned to the question of fish response to supersaturation. “At what depth did they respond?”

In a coho study, Fidler replied, fish moved lower in the water column up to 110 percent supersaturation. Beyond that the dorsal fins went flat and the fish seemed distressed.

Bouck suggested the compilation of a list of anadromous and resident fish stocks which are vulnerable to supersaturation. Snake River fall chinook juveniles may be vulnerable because of amount of time spent at the edge of the river in shallow water.

“Let the river tell us” which species to study, Mesa declared. Which fish are going down the river in May and June, when supersaturation is at its height? Spring, summer, and fall chinook, steelhead, coho, sockeye, lamprey, and shad were suggested.

The problem with this approach, Fredricks stated, is that spill can now be as high in summer as it is in the spring.

In the discussion of sensitive resident fish, Mesa said white sturgeon appears to be sensitive during early life stages.

Grazing species are probably vulnerable, Krise said, because they are frequently on the surface. Many non-resident game fish and others are also spawning there, Bouck noted

“Should we care about non-resident fish?,” Mesa asked

Some of these fish have a constituency, Bouck pointed out. There is now a walleye festival in Umatilla. The lamprey eel is not endearing, he continued, but it is increasingly scarce and may be listed under the Endangered Species Act. But the ecologically important thing is to conserve all the parts.

It is necessary to realize that resource agencies have limited resources, Vic Kaczynski , pointed out, indicating that some species will probably be given priority.

Since different species can be expected to have different tolerances, Mark Zimmerman, ODFW, postulated, an overall assessment may alert managers to problems before they happened, overall insight into supersaturation may be discovered.

Most research indicates that most adult non-salmonids are more tolerant to supersaturation than salmon smolts, Ebel observed.

Because changes in Columbia and Snake River operations have reduced the adequacy of baseline information, Fidler suggested acquisition of data collected at Canadian rivers which have no hydo projects to provide gas supersaturation.

Beiningen expressed discomfort with the prospect of deciding which species are studied, suggesting that it may be a call policy makers should make.

What are the Gas Supersaturation Research Needs for Resident Fish and Invertebrates? (Group Discussion)

Bouck mentioned questions which have been raised about the effect of supersaturation on invertebrates. It has been suggested that dissolved gas may preclude the emergence or transformation of some aquatic insects into adult stages.

Maslen wondered if supersaturation makes predator fish more or less effective as predators.

Fidler said it appears that squawfish have developed strategies to adapt to supersaturation.

There is a void in data about the effect of fluctuations of dissolved gas levels on resident species, according to Dawley. Overall, he said, the effects are not thought to be large. There have been episodes in which problems materialized, he continued, and there is a possibility of progressively more serious problems.

Mesa thought research gains might be possible if new studies are "piggybacked" on those already underway.

Determination of Total Dissolved Gas Effects on Salmon and Other Aquatic Species From Spill at Non Transport Projects. Jim Atheam, Corps of Engineers, Porltand. OR.

Mr Atheam addressed a number of problems associated with efforts to increase the survival of downstream migrants with spill, while contending with the dissolved gas standard and the reappearance of gas bubble disease.

It is important to remember that agencies are "operating in the Endangered Species Act atmosphere." He said monitoring efforts last year by the Fish Passage Center needs to be expanded. The importance of understanding the impacts of new river operations was again stressed. Atheam posed these questions:

1. Can we get more spill. how?
2. Can supersaturation levels be held constant enough for monitoring?

Controlled spill at Ice Harbor this year, at Bonneville and Priest Rapids next year, and later at John Day and The Dalles will increase knowledge of the levels of dissolved gas produced by different amounts and kinds of spill.

Would spill be increased incrementally or in an "on and off" fashion?, Reck wondered. He suggested that the first might produce chronic effects, the latter acute.

Monitoring could be valuable if spill can be held to a particular level at Ice Harbor in 1994, Fredricks noted.

What is the objective of studying this?, Ebel asked

Improving the ability to make correlation's between observed biological effects and spill and dissolved gas levels, Fredericks replied.

It might require another workshop to establish objectives for such an effort, Bouck opined.

Perhaps, Fredricks said, but he stressed the need to make progress this year.

Mesa asked if there was confidence that a controlled "experimental" situation could be created. He suggested that the situation might provide an opportunity to study fish species other than salmonids.

Fidler asked whether observers would be looking for sub lethal or fatal effects.

Fredricks replied by noting that levels of 120 percent are expected on the spillway side and during the summer this level may persist for 24 hour periods. Initially, Ice Harbor results would stand alone; tests would have to be performed at other projects.

If all the dams were spilling, Bouck noted, results at other projects could be modeled.

Noting that Ice Harbor could be the first exposure of fish to supersaturation, Filardo wondered how far downstream effects will be assessed?

Additionally, when does intermittent exposure by individual dams become constant exposure in the downstream areas, Bouck elaborated,?

"Maybe we should be looking at multiple projects," Atheam replied

There is no way researchers can "get at the big picture" in 1994, Maslen commented. It is important for observers to do what they can to produce helpful information.

The situation will permit the collection of data which is more realistic than that produced in the laboratory, Mesa added, and thought it prudent to start small.

Ebel suggested picking "the most valuable pieces of information you can get out of this." Find out from the GASSPILL model what this level of spill would do, then assess effects at the test site. Information like "a 25 percent spill won't produce more than 120 percent supersaturation" might emerge.

It would be possible to use either spill or fish survival as the variable, Fredericks said.

Reach survival studies were brought up again as the best way to determine whether "you are doing any good with spill" according to Ebel A reach could be surveyed while spill is occurring and again when spill is turned off.

Maslen mentioned the pros and cons of having a single detection point.

Atheam reminded the group that there is considerable pressure on the Corps of Engineers to increase spill.

Noting that fish kept in cages could die from air bubble disease, Filardo again raised the question about harming what is to be saved. "What's going to make you feel OK, that you're not doing unacceptable harm?" she inquired.

Fish could be kept in the cage for a single day, Ebel noted, minimizing the risk of mortality.

The problem ofjustifying any fish kill given ESA and the depressed size of salmon stocks was again discussed.

Ebel reminded the group that the alternative to spilling is putting more fish through dam turbines, where bypasses are absent; that tradeoff must be weighed.

"We have to be sure of our information," Giorgi observed.

Assessment of adult returns is also needed, Pettit declared

Shad was suggested as a surrogate for tests involving salmon but Pettit demurred: "We don't know anything about the population dynamics of shad."

The 120 percent supersaturation level was selected for testing 'because that's where we are at," Fredricks explained.

Gary Johnson, BPA said he assumed that the objective is to see how high supersaturation can go before problems materialize.

Whether initial testing should be limited to Ice Harbor or include the entire river system was then debated. If the whole river is included, Ebel said, "you probably don't want to go

higher than 110 percent". He cited Fidler's findings about damage produced at levels higher than 110 percent.

It would depend on how deep the fish are traveling, Fidler replied

Biological Monitoring of Supersaturation in the Columbia River. Earl Dawley, National Marine Fisheries Service, Hammond Bay, OR

Mr. Dawley began by noting that data produced by past monitoring may have lost some of its relevance because spill in the 1960's and 1970's was essentially continuous and it lasted for long duration. He said it is necessary to assess the effects of present operations on anadromous and resident fish and invertebrates.

A Corps funded monitoring program is currently underway by NMFS, and this was described. Sites include several below Ice Harbor, below Priest Rapids, and from Bonneville Dam to the Columbia River estuary Levels of 112 percent supersaturation have recently been found in the estuary.

Fish samples are being taken by beach seining, bottom grabbing, plankton net and electro shock. Captured resident species and hatchery fish are held in a netpen for four days at each of three river reaches. Evaluation of impacts to aquatic species will be related to dissolved gas levels monitored hourly.

Giorgi said testing at the Hanford Reach would be valuable but that people are sensitive about disturbing on the most productive rearing areas on the river.

Atheam asked if monitoring will occur only during spill. Dawley replied it would be during spill and afterwards.

Chuck Willis, asked where the information about saturation levels would be sampled.

At several places in each reach where biological samples were collected, Dawley replied Monitoring would be constant in the net pens.

Bouck asked what species would be test. "All we can catch," Dawley declared

Giorgi wondered if adult salmonids would figure into this assessment and Dawley said the monitoring group hoped to look at adults at Ice Harbor, Lower-Granite, and Bonneville Dams.

To additional questioning, Dawley said net pens will allow movement from the surface to 4 meters in depth and that this particular monitoring effort does not include a control group. "We had hoped to have a week of testing before spill began," he declared, "but by the time Endangered Species Act permits were obtained, they are already spilling."

Bouck worried about how far it would be possible to extrapolate information produced by this effort. Using wild fish that are seined, handled and transported will make it diIIicult to tell whether the results are valid, without having similar fish in a control area that is without gas supersaturation. Also, if fish lack gas bubble disease in the Columbia water, we won't know whether it was able to withstand supersaturation or because it sounded in response to confinement, he suggested.

Shallow water net pens will also be used to evaluate the impacts to fish that were provided no hydrostatic head compensation, Dawley replied.

"Only certain conclusions can be drawn," Fidler observed. Sub lethal effects won't be detected; fish sustaining this level of injury will be eaten later by predators.

You will have a problem drawing conclusions. If external signs of gas bubble disease are detected, there is a problem, Bouck said. But if you don't see these signs, there still may be a problem that would be manifested over a longer period of observation. For example, if you trigger an infection by bacterial kidney disease, it wouldn't show up before the smolt entered the ocean.

"What you are doing is OK as long as you know what kinds of questions you're asking," Fidler added.

To investigate the impact of supersaturation on species diversity, Bouck suggested repeated seining at specified shallow beaches.

Dawley pointed out that determining fish populations is not the objective. The goal is to determine whether there is gas bubble disease.

"So it's a matter of testing the hypothesis, "there is no gross trouble with supersaturation?" Bouck asked.

The concern is what happens to fish held in the net pens, Dawley declared: "If there is no gas bubble disease in them there is no problem; if there is, there is."

"No problem,?" Maslen asked.

Our findings must be couched in terms of the scope of the study, Dawley replied. It is only seeking "signs of severe impacts."

This will provide good information for this year, Mesa declared, but work on sub lethal effects must continue.

A final reservation was voiced by White, who said this monitoring approach won't reveal anything about the effects of supersaturation on invertebrates. However, impacts to invertebrates are indeed part of the research objectives of Dawley.

April 20 - Morning Session

Project Report: Smolt Monitoring by the Fish Passage Center. Margaret Filardo, Columbia - Snake River Fish Passage Center, Portland, OR.

Margaret Filardo described the genesis of the Columbia-Snake River Fish Passage Center, which represents federal, state, and Tribal fish agencies and is funded by the Bonneville Power Administration as part of the Northwest Power Planning Council's Fish and Wildlife Program.

The Fish Passage Center (FPC) conducts a smolt monitoring program. Historically, the FPC monitored dissolved gas concentrations in coordination with the Corps of Engineers Reservoir Control Centers. In response to high dissolved gas concentrations spill would be distributed to various locations throughout the system to minimize the effects of gas supersaturation in any one area.

Monitoring includes smolt traps at headwater sites and crews which examine downstream migrating smolts collected at federal projects.

The magnitude of possible harm was indicated in 199 1 when a fire shut down all the turbines in the John Day Dam. Essentially the entire river was spilled for several days (300,000 KCFS) and supersaturation levels were dramatically elevated. Since the lock at John Day was also out of commission, a barge full of steelhead smolts was emptied and evidence of gas bubble disease was substantial in these steelhead collected at Bonneville Dam.

A dissolved gas trauma symptom program was developed in the wake of this event and it was given impetus by recent moves to assist downstream migrants with spill

Because of the ESA, permits are required for all phases of the program, which focuses exclusively on external evidence of gas bubble disease. Some 100 fish are given detailed examinations three times a week at each project.

Filardo described the protocol for examining fish, which involves breaking down the severity of gas bubble disease symptoms by degree.

In 1993, supersaturation levels of 125 percent were measured for a short time in the forebay at Lower Monumental Dam. Up to 18 percent of the fish examined at that time showed signs ranging from one bubble in a fin to severe.

This high incidence was partially attributable to heavy spill at the dam immediately upstream, Little Goose, which has a spill bay without a deflector and experienced a 24 hour spill when four turbines were not operating.

Criticism of the first year's operation, Filardo said, included the charge "that we didn't see the dead fish" and that bubbles were being absorbed during the up to 24 hour period that fish were held at the transportation sites before being examined.

For the first, she said, no significant changes were found in overall counts of fish recorded by the passage center. In the future, the SMP will monitor fish at the transportation sites at the separator, prior to being held in the sample tank.

Adult fish were sampled at four projects. If the head bum problem described by Ebel recurs this year, Filardo declared, autopsies will be conducted to determine if it is associated with gas bubble disease.

Filardo also had some general comments on spill in Columbia and Snake Rivers. She projected a number of slides showing spill in the 1980s and those projected to achieve a 80 percent fish passage efficiency.

It was noted that the major difference between spill in 1992 and 1993 was natural river flow; 1993 was a relatively good water year, 1992 was not. Most spill "occurs when water can't be held back," Filardo said, showing the relatively smaller impact of voluntary spill for fish.

Filardo pointed out that the Columbia/Snake system runs at between 108 and 109 percent supersaturation even when there is no spill. The standard can be violated "as soon as one drop goes over a spillway."

Bouck said people tend to forget that nature isn't perfect. There are natural conditions where there is too much gas. In the undammed Salmon river, there is both gas supersaturation and heavy smolt mortality, which might be related.

Pettit challenged Bouck and said that he believed the smolt mortality was due to natural predation, not gas supersaturation.

In addition to people monitoring smolt at river projects, Fidler said, "there is another highly trained crew that is operating on the river- - -squawftsh." He asked how predation was being assessed.

The absence of evidence of major decreases in fish abundance at fish passage stations was again cited.

Fidler mentioned the full range of hazards for downstream migrants, turbines, bypass as well as spill.

The proportion of mortality attributable to each of these factors "can be moving around," Fidler suggested.

"We don't make a survival index," Filardo replied. She described the outcome of the monitoring effort as "a predicted abundance curve."

The problem of low velocity of water in the tailrace of dams was discussed. Maslen cited research indicating that 20 percent of the predation at John Day is thought to occur in the tailrace, which is only 1 percent of the reservoir area. Filardo challenged that this original data was being reconsidered and she deferred to Matt Mesa, who said that he had some reservations about that study.

McKem pointed out that smolts are commonly held for 24 hours before being examined and asked how fast symptoms of gas bubble disease can dissipate?

Ebel cited a study at Ice Harbor in which fish lost symptoms of the external signs of the disease in 24 hours.

Bouck suggested that FPC needs to determine the validity of the incidence of gas bubble disease, when they are being held under these circumstances. Filardo said that FPC is already addressing that concern.

Project Report: Effects of Supersaturation on Predation of Smolts. Matt Mesa, National Biological Survey, Cook, Wa.

Mesa described a laboratory study in which fish exposed to supersaturation and those which were not were released into a raceway containing 10 hungry squawfish. The study measures the time until half of the prey fish are eaten and then they determine how many of those devoured had been exposed to supersaturation.

The study was replicated 14 times, Mesa said, and usually more of the gassed smolts were eaten, than control smolts Depending on how one interprets the results, it appears that gas bubble disease can render smolts more susceptible to predation. He raised questions, however, about how realistic the reaction to a single stress factor can be under laboratory conditions.

Ebel asked if the squawfish had been exposed to supersaturation and Mesa said they had not. Mesa said other observations indicated that squawfish are more lethargic, less aggressive, when they are exposed to supersaturation.

Pettit said University of Idaho telemetry studies indicated fish move to avoid high spill Mesa wondered if they were avoiding supersaturation or turbulence.

McKern thought recent predator reduction efforts should be taken into account

Citing the call for a cumulative effects perspective, Giorgi thought swimming ability should also be assessed relative to gas bubble disease and predation. He suggested using active migrating smolts from the river.

Mesa indicated that he probably couldn't get an ESA permit to do this, and besides, wild fish usually do poorly in the lab, he added.

Fidler said the predation experiments were important and should continue but he expressed concern about the crisis nature of current conditions. Answers to predation and other questions may be as long as ten years in coming, he said, and that "could be too late." Because of this, efforts must be made now "to minimize every stress".

This creates a very complicated calculation, Giorgi noted. Spill is thought to be good for the survival of migrants but spill might be precluded if priority is given to reducing all stresses.

Fidler thought managers "could do both" but stressed the "time problem" and said "it may take heroic measures."

McCann said modelers are regularly criticized for considering stress factors separately. "We need to know how these stress factors interact."

Mesa agreed and asked for help in increasing the sophistication of this test.

Bouck said that ODFW reported the greatest amount of predation occurs in the reach below Bonneville Dam. It is also the most downstream project in the system, a good candidate for in-river study of cumulative effects.

The need to consider secondary diseases, those which can occur 20 or 30 days after exposure to supersaturation, was expressed by Dr. John Colt, Montgomery Watson Co

Bouck agreed, mentioning occasions in his own work when fish were not held long enough to determine the true impact. For example, gas supersaturation didn't appear to harm short term survival in sea water, but if the study were repeated, he would run it long enough to assess whether parr reversion occurred in the fall.

Colt cited an example in which bass were transported and survival was evaluated. The initial loss was only 5 percent but fish kept in pens for 30 days all died. Regarding predation, he said long term studies are needed. He pointed out, however; that the cost of long term studies can be more expensive by a factor of ten.

Fidler suggested using rainbow trout as well as squawfish. Mesa said his group assumed the agencies and colleagues expected the work to reflect elements actually at play in the Columbia River. His group does have plans to use small mouth bass and walleye.

Colt said it appears that fish "don't read the same books on supersaturation as we do." "Extreme variation in results, he said, "limits your confidence."

Study **Plan: Allowable Levels of Gas Saturation For Fish Passing Dams.** John Colt and Larry Fidler, Montgomery Watson Co. Bellevue, WA.

Colt and Fidler then described a research project they are conducting in conjunction with Battelle, with funding by BPA. They are conducting a laboratory scale study to evaluate whether a full scale study is indicated. The objective is to determine whether gas supersaturation decreases the ability of smolts to avoid predation following passage through turbines, and smolt bypass systems, versus controls.

Colt diagrammed the hydrostatic pressures fish encounter during passage through turbines. There is a big rise, a big drop, then another rise. The first test is intended to determine how big a toll this experience takes and if it is exacerbated by supersaturation

The second test series will simulate conditions fish experience when they are collected in the bypass system and thusly exercised and deprived of compensatory water pressure. Thresholds for damage to the swim bladder, for bubbles in the environment which can block respiration, and for the occurrence of bubbles in the cardio-vascular system will be investigated. But the central issue is whether the smolts are more susceptible to predation after passing through turbines or bypasses, when the water is supersaturated.

Lucy Bernard, Fish Passage Center, wondered about the dissipation of gas bubble symptoms in the fish bypass trough. It was determined that fish move through this trough very rapidly. Colt noted, however, that smolt bypass facilities differ, some open and others closed, and supersaturation levels vary.

The swim bladder amounts to 6 percent of the total volume of a fish it was pointed out, and the degree to which it is inflated has a big bearing on what happens to a fish passing through a turbine.

Mesa asked what predator species will be used in the experiments? They will be rainbow trout, Fidler replied.

Miller asked Colt and Fidler to compare the pressure history for fish passing through a turbine and those which are spilled. It depends on where they are before they go over the spill, Fidler replied. Colt considered the question beyond the scope of this test.

A range of dissolved gas levels from high to zero will be computer controlled. Adjustments to the level of supersaturation may be needed so that there are enough survivors to continue into the concluding stage. The end point is to determine what effect exposure to dissolved gas has on the ability to avoid predators.

Prey will also be juvenile rainbow trout. Salmon smolts would have been preferable as the prey fish but this was not possible. It is hoped that elements of the developing ultra sound technology can be included in this experiment.

Giorgi thought it unfortunate that a predator known to be a problem in the system could not be used.

Mesa admitted that squawfish are hard to use in predation studies. Colt said Battelle has experience with rainbow and felt more comfortable using that species. Additionally, circumstances require moving ahead with the study now, and using other species would take much more time.

There must always be allowances when the results of laboratory experiments are projected to the field, Bouck declared.

Mesa thought there might be problems with the exposure time, sample size and number of replications in the Colt/Fidler study. He was asked to meet with the research team to discuss these concerns.

Executive Session

April 20,1994 - Afternoon

Bouck reminded the panel that this dissolved gas workshop was convened because federal agencies managing Columbia/Snake River projects have an urgent need to know how much gas supersaturation is too much.

Before proceeding to the final element of the schedule -- listing and prioritizing dissolved gas research needs -- Bouck asked Maslen to elaborate on this need.

Maslen indicated spilling more water during the migration season may improve fish survival at the dam by only between 1 and 1 l/2 percent. To achieve this increased benefit, however, the 110 percent standard for gas supersaturation is regularly violated

Fidler said it was his understanding that levels of 120 and 130 were often produced.

Maslen conceded the point, declaring that operationally, the Corps actively attempts to suppress supersaturation when it reaches 120 percent. He said 110 percent may be an appropriate level from an ecosystem standpoint. The possibility that current spills are already “overstepping the bounds” must be considered, he stated.

Agencies should be finding ways to spill that don’t increase gas supersaturation, Colt declared, mentioning the vertical slot concept which is be tried at the Wells Dam.

This is a promising solution for the future, Maslen replied, but again emphasized the seriousness of the immediate need.

Everything should be looked at now, Colt continued. “We may have to sub-optimally operate the system” until solutions can be found.

Mesa mentioned Filardo’s contention that managers don’t have very much control over involuntary spill.

Maslen agreed, also noting that NMFS is “proposing fish spill with up to 125 percent dissolved gas levels, with increases or decreases in spill based on what we see.”

Ebel noted that elevating supersaturation levels in the whole river would produce long exposure times for fish and take considerable time to turn off, if it is determined that gas bubble disease problems materialized.

Spill would be confined to the migration season, Maslen pointed out.

Fish would continue to be impacted and effects would accumulate over time, Fidler said “We need more direct action to minimize impacts, to concentrate on the dissolved gas problem, he declared.

The Tribes and others propose ending the fish transportation program and increasing spill between 25 and 50 percent, Maslen pointed out. Federal operating agencies must respond to this demand.

At a certain point, Ebel noted, the advantages of spill are lost. These thresholds are “what we need to get a handle on”, Maslen replied.

Jensen recalled results from Fish Passage Center’s monitoring, evidence of damage at some “spill levels which were not too bad.” On the other hand, Colt found these results “fairly shocking evidence. ”

Colts perception was that the supersaturation problem had been fixed 20 years ago and that they weren’t finding any external signs of gas bubble disease anymore.

The problem should have been more addressed more adequately 25 years ago, Bouck said, “when salmon populations were big enough for experimentation. But when spill ended, everyone thought the problem had ended and agencies dumped their research projects on gas bubble disease and supersaturation.

Maslen mentioned a proposal by Fredricks which could not be undertaken in current circumstances. Conditions of extreme dissolved gas could be set up for three years and the impact on returning adults observed.

Beiningen wondered if the effects of supersaturation could be logarithmic, that between 110 and 125 percent, impacts "could skyrocket." In the current situation, he said, it's "damned if you do and damned if you don't."

He expressed surprised of elements of the NMFS proposal, characterizing it as being "down to the last mile" with "no second chances."

The incidence of gas bubble disease reported by Fish Passage Center monitoring "had to be understated," Ebel declared, because the signs would have diminished or disappeared during the 24 hours fish were in equilibrated water.

In addition, Dawley said, the levels of supersaturation at Ice Harbor were not reported

Maslen reduced the issue to this question: "can you experts say that a supersaturation of 120 percent is a problem?"

The panel reached a consensus that the answer was "Yes, it is a problem", but Dawley added that "how long?" and "where?" were questions which had to be asked.

White said he was surprised that evidence for the survival benefits of spill was not more abundant and firm.

Survival data hasn't been gathered since 1980, Ebel declared. This was partially because large scale transportation of fish dramatically altered conditions and partially because some people didn't want to know what was happening, he opined. System survival studies "are a crying need." They are running models with nothing in them. Worse than that, Ebel said, they are "running the river on B.S.!"

"We know more about gas bubble disease than we do about the benefits of spill," Dr. Gary Chapman EPA, suggested.

Dawley agreed that knowledge of both issues are required to permit the selection of a rational tradeoff. "If you are losing 50 percent of the fish to save a few fish, what are you accomplishing?"

The possibility of using video to pursue a research objective was then discussed and Maslen turned discussion back to the immediate problem. "Spill started last week," he said, adding that elevated levels of dissolved gas would begin with the freshet. Decisions have to be made immediately. He asked for the assistance of the workshop panel for on-going consultation. A half-dozen questions need to be addressed as soon as possible, he declared.

Fidler suggested that some of the urgency may be relieved if 1994 continues to be a low water year.

The panel agreed to ask the Fish Passage Center to have its smolt observers look for bubbles in the lateral line, using a dissecting microscope if necessary. Ebel suspected that this will disclose a much larger number of problem fish.

When fish develop lateral line bubbles in highly supersaturated water, Fidler declared, the bubbles could continue to grow even after the level drops to 105 percent.

The threshold for levels in which bubbles continue to grow should be established, McCann declared.

Will the bubble disappear if the level declines to 100 percent, Ebel asked, and Fidler said it would.

Colt said to be prepared for objections from people who will say “we don’t see any dead fish.” “We don’t see dead fish as a result of passage through turbines,” Maslen said, adding that “no one credibly denies that it is happening.”

The remainder of the session was given over to selecting and prioritizing a list of dissolved gas research project assembled by facilitator Hugh Moore.

High Priority Research Projects 00 Gas Supersaturation and Gas Bubble Disease

The "high priority" projects listed below were derived from an original list of over 40 identified research needs. These were selected by ballots from the Panel of Experts, but are not listed here in priority order.

- Study the cumulative effects of gas supersaturation in conjunction with other stresses on fish survival.
- Develop additional information on spatial distribution in relation to dissolved gas levels.
- How can we monitor the effects of gas supersaturation without harming fish?
- Study the effects of present (changes in) river operations on the incidence of gas bubble disease and dissolved gas in the river.
- Validate a monitoring program for gas bubble disease and total dissolved gas.
- Compare results of monitoring on the Columbia River with studies of other river systems.
- Conduct fish survival studies across the hydro system relative to gas supersaturation in the Columbia and Snake Rivers.
- Determine gas supersaturation impacts on resident fish in the Columbia and Snake Rivers.
- Assess the stress responses, resistance to infections diseases, and other sub lethal effects in fish subjected to various levels to total dissolved gas.
- Assess the vulnerability of salmonids to predation subjected to various levels to total dissolved gas.
- Evaluate the positive and negative effects of spill, bypass, turbines, and transportation on fish survival.
- Predict the cumulative impact of intermittent spills on total dissolved gas in the Columbia River.
- Improve understanding an predictive models for air entrainment at spillways.

Additional Research Opportunities: (available upon request)

List of Attending Experts on Gas Supersaturation and Gas Bubble Disease:

Dr. Larry E. Fidler, Aspen Applied Sciences, Vancouver, B.C. 604-566-993 1
Mr. Earl Dawley, NMFS, Hammond, OR 503-861-l 853
Dr. Robert White, Montana Coop Fish Research Unit, Bozeman, MT 406-994-349 1
Mr. Matt Mesa, NBS, Columbia River Research Lab, Cook, WA 509-538-2299
Mr. John Jensen, Pacific Biological Station, Nanaimo, B.C. 604-756-7013
Dr. William Krise, National Biological Survey, Wellsboro, PA. 7 17-724-3322
Kirk Beiningen, ODFW, Clackamus, OR 503-657-2038
Dr. Gerald Bouck, BPA, Portland, OR 503-23 l-698 1 692-4907 after May 1,1994)
Dr. Wesley Ebel, NMFS (retired), Seattle, WA 206-542-2978
Dr. Gary A. Chapman, EPA, Newport, OR. 503- 867-4027

Other Attendees: (may not be complete)

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Celia Kool, COE, 503-326-6586
Jim Ceballas, NMFS, 503-230-5405
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